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4. DIKE STABILITY

4.1 Problem

Adequate factors of safety against slope failures must be maintained. Possible types of failures include "liquefaction" failures caused by earthquakes, and shallow failures that might take the form of a series of progressive slides. An adequate factor of safety has been calculated by SHB and other consultants (see Table 4.1) for the overall general slope failure condition for the static case. Due to conditions described below, it is possible that localized shallow failures or sloughing may develop. The potential for shallow failures is greatest where water is present at or within about three or four feet of the surface of the exterior face of the dam. This condition presently exists about 15 feet vertically from the dam crest over portions of the east and north sides.

Shallow failure can be caused by erosion from broken pipelines, overflow from spigots if beaches are not maintained, and construction activities on the face of the dam, such as, excavations or the operation of bulldozers or other equipment that cause a high level of vibration. Other less likely, but possible causes of shallow slides, are "sand boils" or piping caused by ponding of water very near the crest of the dam and freezing the face of the dam during a very cold winter.

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4.2 Methods to Control Dike Stability

The methods to control dike stability include:

1. Lowering the water surface below the crest (by widening the beach).
2. Detection and repair of pipeline leaks, overflow at spigots and "wash outs" down the face of the dam.
3. Treatment of any sand boils or areas of large seepage on the face (more than 1/2 gpm over a 25 square foot area).

The depth to the water surface below the crest and slope of the disposal facility generally increases with distance from the crest to the reclaim pond or channel of free flowing water (e.g. the width of the beach). A theoretical estimate water level that may be achieved by widening the beaches is shown on Sheets 1 and 2 in the addendum to the design report. The beach building requirements in Section 4 are based on these water level estimates and are projected to increase the factors of safety. This consideration indicates that the width of beach be extended to 800 feet at the new reclaim siphons and 2,000 feet around the rest of the dam perimeter and maintained at these target widths. It is expected to take up to one year to achieve these widths.

The estimated target depths to groundwater in selected piezometers, to be achieved by widening the beaches, are listed in Table 4.1 (description of the piezometers is presented in Section 9.3). Approximate factors of

2. SLOPE STABILITY

In the early part of our work on the project we were asked by KUC to perform geotechnical work on the new peripheral discharge pipeline system. We had been unaware of the construction details or construction schedule for this system prior to that time. As you know, ultimately, 271 shallow piezometers were installed, and extensive shallow water either seeping from the surface or within 2 or 3 feet of the surface was found. Stabilization with geotextiles and slag was used in many areas, and extensive sand boils and larger seeps developed. This is apparently perched water underlain by zones of slimes of low permeability although it is uncertain whether saturated or unsaturated layers underlie these areas. The high vertical downward gradients measured in some piezometers suggest water perched over slimes of very low permeability which in turn rest on interlayered sands and slimes.

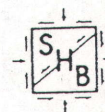
This condition seemed to me much more widespread than indicated by earlier reports and piezometer readings. For comparison a summary various stability analysis is shown in Table 2. Crosssections for several of these stability analysis are presented in Appendix B and locations are shown on the map in the map pocket. The approximate location of the type of perched water measured in the SHB piezometers are shown on these sections.



The dam seems to be safe for static cases based on drained shear strengths even with a high water level. As shown in Table 2, we calculated a factor of safety of 1.23 for the water level at the surface. We used effective stress shear strength of $\phi = 36$ degrees and $c = 0$, and a buoyant unit weight of 60 pcf in this analysis, which was for a shallow surface in a steeper area of the slope at Section A- A'. Dames and Moore (1983), and Woodward Clyde and Sherard (1965) obtained factors of safety of 1.18 and 1.25 for similar analysis with deeper failure surfaces.

In our judgement, the most probable "static" slope failures are associated with undrained rather than drained shear strength. The most serious potential type of an undrained failure is, of course a seismically induced liquefaction failure as evaluated by Kohn Leonoff (1987).

The rate of building of the dam is so slow that appreciable excess pore pressures are not built up. However, ways that excess pore pressure could be built up at shallow depths are construction excavations, vibrations from bulldozers or other equipment, gullyng from water line leaks or overtopping of spigot flow and freezing and thawing during an extremely cold winter. All of the possibilities are unlikely, but because of the consequences of failure we believe it is important to draw the water surface down as quickly as possible although the risk of these kind of events is small, it



is more or less proportional to the area of very shallow water which is now quite extensive.

The most likely mechanism of failure is a progressive series of shallow slides. The steeper areas on the generally flat slopes are most susceptible to this. As indicated in our original report, only a relatively small buildup of excess pore pressure would be necessary to cause this type of failure.

3. RECOMMENDED SIPHON EXTENSION

Figures 5 and 6 on a drawing in the map pocket show the recommended concept for the causeways and siphon extension described in Section 2.5.1.1 of our original report. The details of this concept were based on discussions with KUC. Two independent 40-foot wide causeways were used because of risk of construction damage during raising of the causeways and siphons. The siphons were moved to the location shown in Figure 1.2 (where the slope is still 7H:IV) to shorten the new pipeline to the clarification canal.

The causeways would be built to a level 4-foot surface above the beach for each raise, with riprap slope protection placed as needed. Although rockfill or gravel was anticipated as fill, it may be possible to effect savings with the use of cycloned sands.

An average beach width of about 800 feet and 4 feet of



TABLE 4.2

Section	Water Level h_1	Water Level h_2	Static Factor of Safety	Remarks
A-A' 5:1 Slope (horizontal to vertical)	15	0-8'	1.54	Existing Condi- tion June 1988
	28	10	1.61	Intermediate Water Surface
	41	20	1.93	Intermediate Water Surface
	54	31	2.47	Target Water Surface
B-B' 7:1 Slope (horizontal to vertical)	15	0-8'	2.19	Existing Condi- tion June 1988
	23	9	2.37	Intermediate Water Surface
	31	18	2.51	Intermediate Water Surface
	39	27	2.63	Target Water Surface

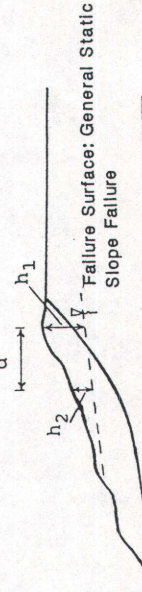
Note: Factors of safety apply to general static slope failure. See inset based on the following drained shear strength parameters and unit weights:

$$\phi = 30^\circ$$

$$c = 0$$

$$\text{Wet Unit Weight} = 124 \text{ pcf}$$

$$\text{Dry Unit Weight} = 112 \text{ pcf}$$



Section	d (feet)
A-A'	130
B-B'	170